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# (54) Cellular Radiocommunication System

(57) A cellular radiocommunication system (1) includes a plurality of cells (2, 3), each cell having a cell transmitter and a cell receiver providing a cell-wide communication channel. The cells (2, 3) are each divided into a number of coverage areas (3 - 8), each coverage area (3 - 8) having a base station (9 - 14) including a transmitter and a receiver providing an area-wide communication channel and a monitoring receiver for monitoring signals from mobile units in neighbouring coverage areas. A controller (15) is connected to the base stations (9, 10, 11) in one cell (2) and to the cell transmitter and cell receiver for determining whether a mobile unit (18, 19) communicating on an area-wide communication channel should continue its communication on another area-wide communication channel in the cell (2) or on the cell-wide communication channel or whether a mobile unit (18, 19) communicating on the cell-wide communication channel should continue its communication on an area-wide communication channel.

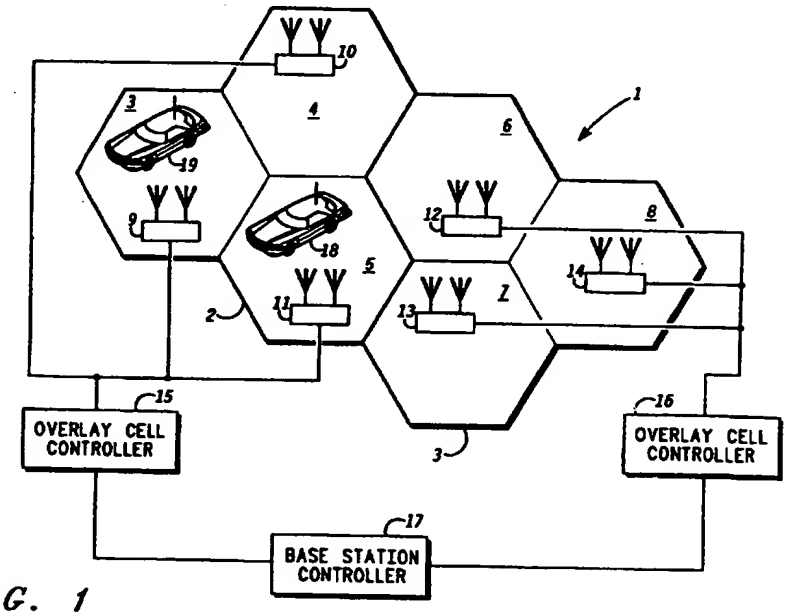


FIG. 1

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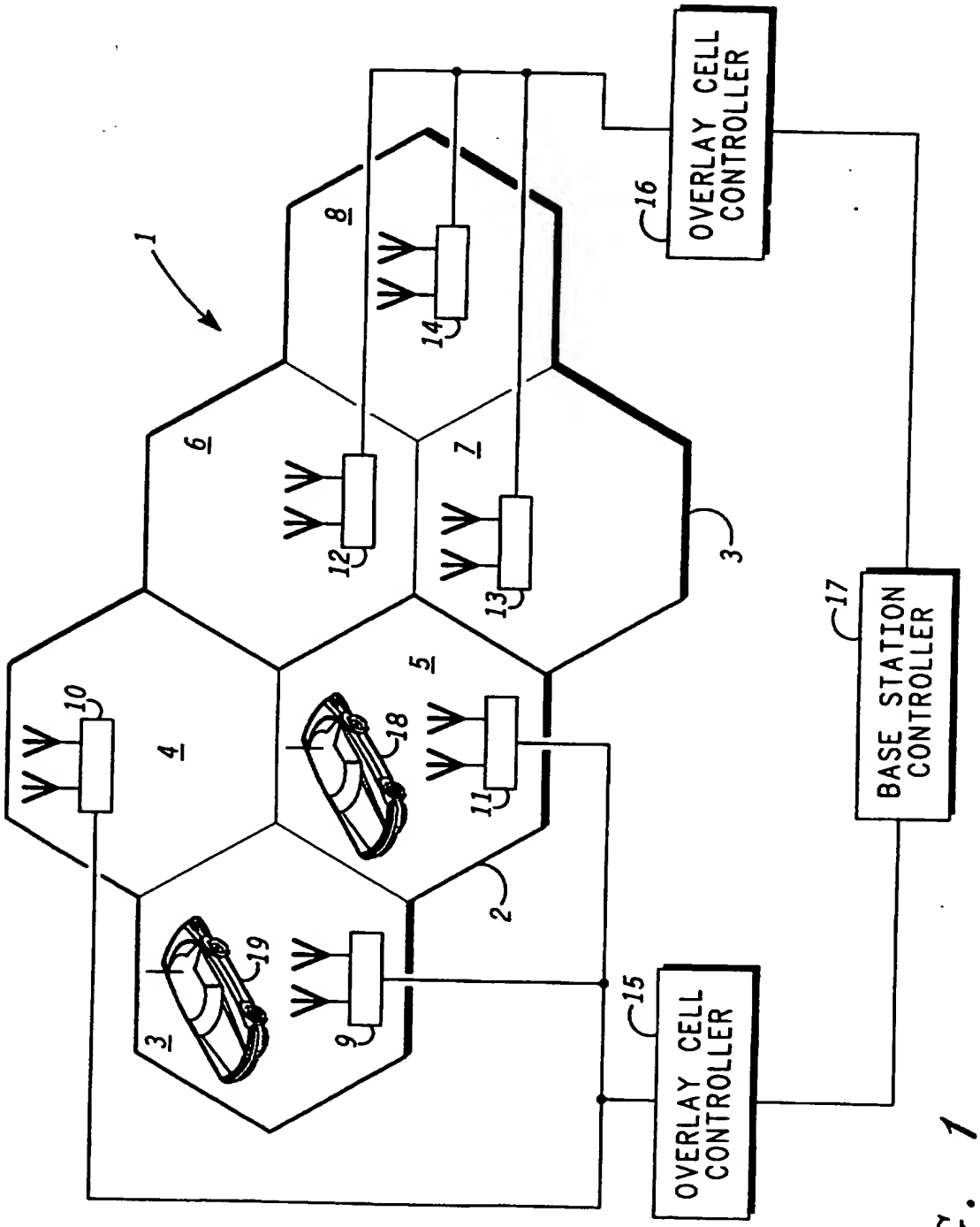
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OVERLAY CELL CONTROLLER
OVERLAY CELL CONTROLLER
BASE STATION CONTROLLER

FIG. 1

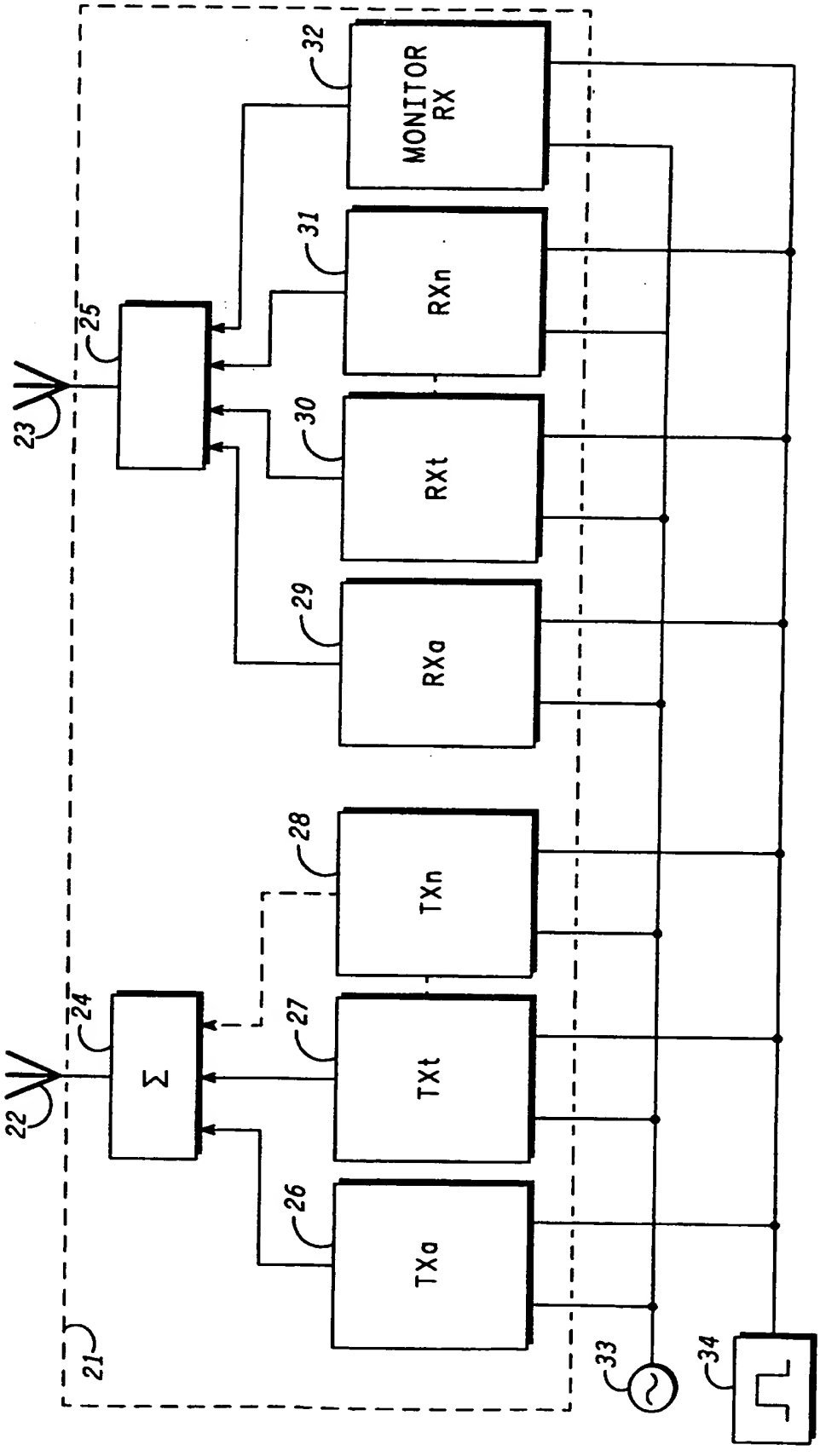
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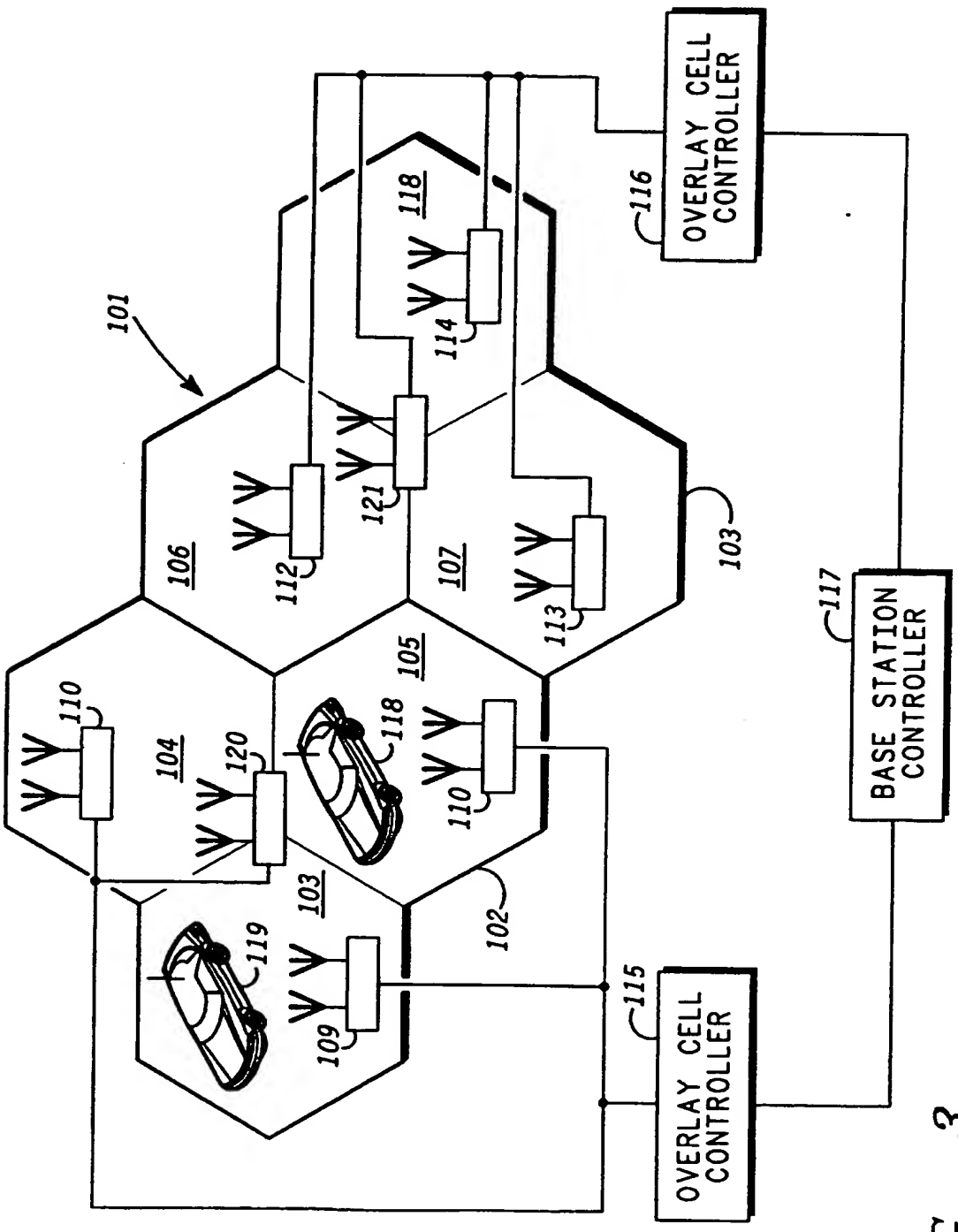
FIG. 2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OVERLAY CELL CONTROLLER
OVERLAY CELL CONTROLLER
BASE STATION CONTROLLER

FIG. 3

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# CELLULAR RADIOCOMMUNICATION SYSTEM

## Field of the Invention

This invention relates to a cellular radiocommunication system, and more particularly to such a system in which each cell can be subdivided in order to increase the capacity of users.

## Background of the Invention

In cellular radiocommunication systems, the area to be served is divided into a number of cells, each of which has a base station, which transmits cell identity information to nearby mobile stations and which provides channels for communication with the mobile stations. To avoid interference of communication between cells, different radio frequencies are used in neighbouring cells, but the frequencies are re-used in more distant cells. When communication is to be initiated, the base station transmits and receives voice or data communication to and from the mobile station and controls the operation of the mobile station, including the channel to be used for the communication. The base station and/or the mobile station monitors the strength and quality of the received signal and will hand-over the communication to an appropriate neighbouring cell if the strength or quality falls below a defined threshold.

As will be appreciated, the system has a limited number of channels available for communicating with mobile stations. One known way of increasing the capacity of the system is to divide each cell into a number of microcells, each of which function in a similar manner to a cell. Thus, each microcell transmits its identity information to nearby mobile stations on a frequency different to that of adjacent microcells and performs hand-over of the mobile station to an adjacent microcell, as appropriate.

A fast moving mobile station will move rapidly through a microcell, which typically is a few hundred metres across. The time taken for hand-over to occur can become a significant proportion of the time spent in a single microcell. This will cause a degradation in quality of the communication in progress and may cause communication to cease through failed hand-over.

## Brief Summary of the Invention

The present invention therefore seeks to provide a cellular radiocommunication system which overcomes, or at least reduces the above-mentioned problems of the prior art.

Accordingly, the invention provides a cellular radiocommunication system comprising a plurality of cells, each cell having at least one cell transmitter and at least one cell receiver providing at least one cell-wide communication channel, at least one of the cells being divided into at least two coverage areas, each coverage area having a base station including a transmitter and a receiver providing an area-wide communication channel and a monitoring receiver for monitoring signals from mobile units in at least one neighbouring coverage area, and a controller coupled to each of the base stations in said one cell and to the cell transmitter and cell receiver for determining whether a mobile unit communicating on an area-wide communication channel should continue its communication on another area-wide communication channel in the cell or on the cell-wide communication channel or whether a mobile unit communicating on the cell-wide communication channel should continue its communication on an area-wide communication channel.

In a preferred embodiment, each base station includes a transmitter and receiver providing the cell-wide communication channel(s). In one embodiment, signal quality and/or strength of communication between a mobile station and a first base station on an area-wide communication channel is measured by both the receiver of the first base station and the monitoring receiver of at least one other base station in a neighbouring coverage area and the measured values of the signal quality and/or strength are sent to the controller. In a further embodiment, signal quality and/or strength of communication between a mobile station and the cell transmitter and cell receiver of a first base station on a cell-wide communication channel is measured by both the cell receiver of the first base station and the cell receiver or monitoring receiver of at least one other base station in a neighbouring coverage area and the measured values of the signal quality and/or strength are sent to the controller.

Preferably, the controller includes means for comparing the measured values and means for sending, via the first base station, to the mobile station a

control signal instructing the mobile station to communicate on a different communication channel if the compared value of the signal strength and/or quality measured in another base station is better than the signal strength and/or quality measured in the first base station. Alternatively, the controller includes means for comparing the measured values and means for sending to another base station a control signal for the other base station to switch to the area-wide communication channel to communicate with the mobile station if the compared value of the signal strength and/or quality measured by the monitoring receiver of that other base station is better than the signal strength and/or quality measured by the receiver of the first base station.

Alternatively, however, a central cell base station can be provided to include the transmitter and receiver providing the cell-wide communication channel(s). Preferably, in such an embodiment, signal quality and/or strength of communication between a mobile station and a first base station on an area-wide communication channel is measured by both the receiver of the first base station and the monitoring receiver of at least one other base station in a neighbouring coverage area and the measured values of the signal quality and/or strength are sent to the controller. Preferably, the controller includes means for comparing the measured values and means for sending, via the first base station in communication with the mobile station, a control signal to the mobile station instructing the mobile station to communicate on a different communication channel if the compared value of the signal strength and/or quality measured in another base station is better than the signal strength and/or quality measured in the first base station in communication with the mobile station. In a further embodiment, signal quality and/or strength of communication between a mobile station and the cell base station on a cell-wide communication channel is measured by both the cell receiver and the monitor receiver of at least one base station and the measured values of the signal quality and/or strength are sent to the controller. Preferably, the controller includes means for comparing the measured values and means for sending, via the cell base station in communication with the mobile station, a control signal to the mobile station instructing the mobile station to communicate on a different communication channel if the compared value of the signal strength and/or quality measured in another base station is better than the signal strength and/or quality

measured in the cell base station in communication with the mobile station. Alternatively, the controller includes means for comparing the measured values and means for sending to another base station a control signal for the other base station to switch to the area-wide communication channel to communicate with the mobile station if the compared value of the signal strength and/or quality measured by the monitoring receiver of that other base station is better than the signal strength and/or quality measured by the receiver of the first base station.

Preferably, each cell has a cell identity which is transmitted on a cell-wide channel. Conveniently, the controller controls all the base stations within the one cell. A preferred embodiment further comprises a cell controller coupled to the controller and to at least one further controller of a neighbouring cell for determining whether the mobile unit should be handed off to continue its communication with the neighbouring cell.

## Brief Description of the Drawings

Two embodiment of the invention will now be more fully described, by way of example, with reference to the drawings, of which:

FIG. 1 shows a first embodiment of a system according to the invention;

FIG. 2 shows a block diagram of a base station used in the system of FIG. 1; and

FIG. 3 shows a second embodiment of a system similar to that of FIG. 1.

## Detailed Description of the Drawings

Referring firstly to FIG. 1, a communications system 1 comprises a plurality of cells, of which two cells 2, 3 are shown. The cells 2, 3 are each divided into at least two, in this embodiment three, coverage areas 3 - 8. It will be appreciated that not all cells in the system need be so divided and that, if a cell is divided into converage areas, there could be any number of coverage areas in any particular cell, so that, for example one cell could be undivided, an adjacent cell could be divided into two coverage areas and a third adjacent cell could be divided into, for example, four coverage areas.

Each coverage area 3 - 8 contains a microcell base station 9 - 14, respectively. All of the microcell base stations 9, 10, and 11 in a particular cell 2 are connected to an overlay cell controller 15. A number of overlay cell controllers 15, 16 are connected to a base station controller 17 which controls hand-over between cells, as in a normal cellular radiocommunication system.

As shown in FIG. 2, a microcell base station 21 includes a transmitting antenna 22 and a receiving antenna 23. More than one antenna may be used for diversity reception, and a single antenna may also be used for both transmission and reception. Each microcell base station 21 contains one transmitter 26 and one receiver 29 which operate on the same frequency allocation for all of the microcell base stations within a single cell. This is here termed the overlay carrier. The transmitter 26 transmits cell identity information and paging information on a channel for the cell in which the coverage area is located. In this embodiment, a channel is defined as a combination of frequency allocation and timeslot in a time division multiple access communication system.

In a radio communication system employing frequency division duplex, a single frequency allocation will consist of one RF carrier frequency for transmission, and a second RF carrier frequency for reception. In a radio communication system employing time division duplex, a single RF carrier frequency will be used for both transmission and reception. In general, the overlay frequency allocation used in one cell 2 will be different from that used in a neighbouring cell 3.

Each microcell base station 21 also includes at least one further transmitter 27 and receiver 30. A microcell base station may contain extra transmitters 28 and receivers 31, in pairs. In general the frequency allocations used by one microcell base station for these transmitters and receivers will be different from microcell base stations in other coverage areas within the same cell. Generally, the set of frequency allocations used in the coverage areas within one cell will be re-used in neighbouring cells. The output from each transmitter 26, 27, 28 in the microcell base station 21 is combined by a combining network 24 to feed the transmitting antenna 22.

Each microcell base station 21 also includes at least one further receiver 32. This monitoring receiver is used to monitor the strength and/or the quality of the signal from mobile stations 18, 19 operating in different coverage areas 3, 5 within the same cell 2 from the coverage area 4 in which the microcell base station 10 is located 4. The signal received by the receiving antenna 23 is fed to each receiver 29, 30, 31, 32 by a distribution network 25.

The frequency of the transmission of the overlay carrier transmitted by each microcell base station in a cell must be very accurately controlled, which

generally requires an external frequency reference 33. It is necessary to maintain a defined relationship in the timing of the transmissions of the overlay carrier from each microcell base station in a cell, which generally requires an external timing reference 34. It may also be desirable for the other transmitters and receivers within the microcell base station to use the same timing and frequency references (this is a requirement of the GSM system).

If a mobile station receives the overlay carrier from two or more microcell base stations, the received signal will be the result of the vector addition of the RF field from the transmissions of the microcell base stations. In some locations there will be nulls, in which the received signal strength is less than would result from the signal being received from only one base station. The effect of the nulls may be reduced by periodically changing the relative phase of the RF signal transmitted by the microcell base stations. This will mean that a null will only occur in a particular location for a proportion of the time. For a signal which employs time division multiple access, such as GSM, the change of phase may be made between timeslots without affecting the characteristics of the transmission during the useful part of the bursts. In order for inter-symbol interference not to occur with a digital communication system, the difference in RF propagation delay of the signal received from all significant microcell base stations must be small compared to a symbol period.

If the receiver in the mobile station 18, 19 incorporates an equaliser, then the overlay carrier transmitted by the microcell base stations in a cell may be accurately synchronised in frequency, but with the timing of the modulated data offset by a period of up to a few bits, but less than the constraint length of the equaliser. It is also possible to vary both the RF Phase and the data timing.

A call is initiated using a channel on the overlay carrier. When a mobile station 18 transmits on an overlay channel, the signal will be received by all neighbouring microcell base stations 9, 10 and 11. The received signal and a report of the signal strength and/or quality is sent from these microcell base stations to the overlay cell controller 15. The overlay cell controller 15 selects which microcell base station should handle the call. This decision may be made on the basis of received signal strength, received signal quality

or available capacity to handle further calls. It is also possible for the overlay cell controller 15 to use soft decision decoding, making use of the signal received from more than one microcell base station.

Once a call has been initiated, the overlay cell controller 15 may perform an intra-cell handover, to move the call to a channel on one of the carriers other than the overlay carrier, for which communication will be between the mobile station 18 and a single microcell base station 11.

Each microcell base station 21 will measure the received signal strength and/or quality from mobiles in neighbouring coverage areas. For the overlay carrier this is performed using the receiver 29 for the overlay carrier. For the remaining frequency allocations in use in neighbouring areas, this is performed using the monitoring receiver 32. As a mobile station moves out of a coverage area, the call is transferred to a microcell base station in a neighbouring coverage area by instructing the mobile station to change its channel to one in the frequency allocation of that coverage area. This process is known as intra-cell handover. The overlay cell controller 15 uses the measurement reports from the monitoring receivers in the microcell base stations in neighbouring coverage areas to select the correct coverage area to transfer the call.

The overlay cell controller 15 can estimate the speed of the mobile station using the rate of change of the relative signal strengths reported by the microcell base stations within the cell. If the mobile station is moving fast, it will cross rapidly between the coverage areas within the cell; the relative signal strengths will change rapidly and it is preferable for the call to remain on or be returned to the overlay carrier, which is available throughout the cell. When the overlay carrier is used, the probability that a call will be lost during intra-cell handover is reduced, and the need for signalling between the mobile station and network during handover is avoided.

When a call in progress is transferred from one microcell base station to another, the overlay cell controller may perform an intra-cell handover to the frequency allocation of the new base station, in the previously described manner. Alternatively, it may transfer the frequency allocation of the channel in use to the microcell base station to which the call is being transferred. In this case, the mobile station is not aware of any hand-over occuring. It is important that the transfer of a call in progress does not cause

interference to calls already underway in nearby cells or coverage areas using the same frequency allocation. The overlay cell controller has knowledge of the frequency allocations in use in other coverage areas within the cell. The frequency allocations in use in neighbouring cells can be reported to the overlay cell controller, for instance, via the base station controller 17. The overlay cell controller can use this knowledge of frequency allocations, together with measurements made by neighbouring microcell base stations and records of interference levels from previous calls and hand-overs, to determine whether it is possible to transfer the call between microcell base stations without changing channel. If it is not possible, an intra-cell handover is performed.

Thus, the mobile station does not need to be informed that the cell is comprised of a number of microcell base stations. No extra functionality is required of the mobile station in order to operate with a cellular system containing microcell base stations.

For handovers between cells, the normal inter-cell handover procedures can be used. The overlay cell controller can use the reported signal strengths from a plurality of microcell base stations to estimate the position of the mobile station within the cell. This estimated position can then be used to enhance the inter-cell handover procedures.

In an alternative embodiment, as shown in FIG. 3, the microcell base stations 103, 104, 105 do not contain the transmitter 26 and receiver 29 for the overlay carrier. These are contained in an overlay base station 120, which is capable of communicating with a mobile station throughout the cell 102. This overlay base station 120 does not need to contain any of the other transmitters 27, 28, receivers 30, 31 or the monitor receiver 32. In this embodiment, intra-cell handover can occur between the overlay base station and the microcell base stations within the cell, or between the microcell base stations.

Although, where relevant, this embodiment has been described by reference to the GSM system for mobile communications, it will be appreciated that it can be applied to other cellular radiocommunication systems.

It will further be appreciated that although only two particular embodiments of the invention have been described in detail, various

modifications and improvements can be made by a person skilled in the art without departing from the scope of the present invention.

## Claims

1. A cellular radiocommunication system comprising a plurality of cells, each cell having at least one cell transmitter and at least one cell receiver providing at least one cell-wide communication channel, at least one of the cells being divided into at least two coverage areas, each coverage area having a base station including a transmitter and a receiver providing an area-wide communication channel and a monitoring receiver for monitoring signals from mobile units in at least one neighbouring coverage area, and a controller coupled to each of the base stations in said one cell and to the cell transmitter and cell receiver for determining whether a mobile unit communicating on an area-wide communication channel should continue its communication on another area-wide communication channel in the cell or on the cell-wide communication channel or whether a mobile unit communicating on the cell-wide communication channel should continue its communication on an area-wide communication channel.

2. A cellular radiocommunication system according to claim 1, wherein each base station includes a cell transmitter and cell receiver providing the cell-wide communication channel.

3. A cellular radiocommunication system according to claim 2, wherein signal quality and/or strength of communication between a mobile station and a first base station on an area-wide communication channel is measured by both the receiver of the first base station and the monitoring receiver of at least one other base station in a neighbouring coverage area and the measured values of the signal quality and/or strength are sent to the controller.

4. A cellular radiocommunication system according to claim 2, wherein signal quality and/or strength of communication between a mobile station and the cell transmitter and cell receiver of a first base station on a cell-wide communication channel is measured by both the cell receiver of the first base station and the cell receiver or monitoring receiver of at least one other base station in a neighbouring coverage area and the measured values of the signal quality and/or strength are sent to the controller.

5. A cellular radiocommunication system according to either claim 3 or claim 4, wherein the controller includes means for comparing the measured values and means for sending, via the first base station, to the mobile station a control signal instructing the mobile station to communicate on a different communication channel if the compared value of the signal strength and/or quality measured in another base station is better than the signal strength and/or quality measured in the first base station.

6. A cellular radiocommunication system according to claim 3, wherein the controller includes means for comparing the measured values and means for sending to another base station a control signal for the other base station to switch to the area-wide communication channel to communicate with the mobile station if the compared value of the signal strength and/or quality measured by the monitoring receiver of that other base station is better than the signal strength and/or quality measured by the receiver of the first base station.

7. A cellular radiocommunication system according to claim 1, wherein a cell base station includes the cell transmitter and cell receiver providing the cell-wide communication channel.

8. A cellular radiocommunication system according to claim 7, wherein signal quality and/or strength of communication between a mobile station and a first base station on an area-wide communication channel is measured by both the receiver of the first base station and the monitoring receiver of at least one other base station in a neighbouring coverage area and the measured values of the signal quality and/or strength are sent to the controller.

9. A cellular radiocommunication system according to claim 8, wherein the controller includes means for comparing the measured values and means for sending, via the first base station in communication with the mobile station, a control signal to the mobile station instructing the mobile station to communicate on a different communication channel if the compared value of the signal strength and/or quality measured in another base station is better

than the signal strength and/or quality measured in the first base station in communication with the mobile station.

10. A cellular radiocommunication system according to claim 7, wherein signal quality and/or strength of communication between a mobile station and the cell base station on a cell-wide communication channel is measured by both the cell receiver and the monitor receiver of at least one base station and the measured values of the signal quality and/or strength are sent to the controller.

11. A cellular radiocommunication system according to claim 9, wherein the controller includes means for comparing the measured values and means for sending, via the cell base station in communication with the mobile station, a control signal to the mobile station instructing the mobile station to communicate on a different communication channel if the compared value of the signal strength and/or quality measured in another base station is better than the signal strength and/or quality measured in the cell base station in communication with the mobile station.

12. A cellular radiocommunication system according to claim 8, wherein the controller includes means for comparing the measured values and means for sending to another base station a control signal for the other base station to switch to the area-wide communication channel to communicate with the mobile station if the compared value of the signal strength and/or quality measured by the monitoring receiver of that other base station is better than the signal strength and/or quality measured by the receiver of the first base station.

13. A cellular radiocommunication system according to any preceding claim, wherein each cell has a cell identity which is transmitted on a cell-wide channel.

14. A cellular radiocommunication system according to any preceding claim, wherein the controller controls all the base stations within the one cell.

15. A cellular radiocommunication system according to any preceding claim, further comprising a cell controller coupled to the controller and to at least one further controller of a neighbouring cell for determining whether the mobile unit should be handed off to continue its communication with the neighbouring cell.

16. A cellular radiocommunication system substantially as hereinbefore described with reference to the drawings.

| Patents Act 1977<br>Examiner's report to the Comptroller under Section 17<br>(The Search report) | Application number<br>GB 9522268.3 |
|---|---|
| **Relevant Technical Fields**<br>(i) UK Cl (Ed.N) H4L (LDSG, LDSH)<br>(ii) Int Cl (Ed.6) H04Q 7/36, 7/38 | Search Examiner<br>MR N HALL<br>Date of completion of Search –<br>10 JANUARY 1996 |
| **Databases** (see below)<br>(i) UK Patent Office collections of GB, EP, WO and US patent specifications.<br>(ii) | Documents considered relevant following a search in respect of Claims :-<br>1-16 |

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